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PATENT TRADEMARK OFFICE

164.1014.01

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9

Title of the Invention

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11 Synchronized Plural Channels for Time Division Duplexing

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13 Background of the Invention

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15 *1. Field of the Invention*

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17 This invention relates to communication that uses time division duplexing (TDD)  
18 for multiple communication channels. In particular, the invention relates to synchronizing the  
19 duplexing across the plural channels, and further to assigning slots for time division multiple  
20 access (TDMA) in those channels such that consumer provided equipment (CPE) dynamically  
21 switches channels.

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*2. Description of the Related Art*

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24 Time division duplexing (TDD) is a well-known technique for bi-directional  
25 communication over a single frequency channel. In TDD, the channel is temporally divided into  
alternating upstream and downstream frames.

1                   Communication between a base station and several consumer provided equipment  
2 (CPEs) can share a single TDD channel through use of time division multiple access (TDMA).  
3                   In TDMA, the upstream frames and the downstream frames are subdivided into plural slots. The  
4 base station allocates these slots among the CPEs. At a start of each downstream frame (i.e.,  
5 from the base station to the CPEs), the base station sends data to the CPEs about the slot  
6 allocation, usually using media access protocol (MAP) messages.

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8                   Sometimes, a base station communicates with plural CPEs using TDMA on plural  
9 channels. Conventionally, each CPE is assigned to a channel, and the CPE receive MAP and data  
10 bursts and sends data bursts only on its assigned channel. This arrangement is shown in Fig. 4.

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12                   CPEs A to H in Fig. 4 communicate using TDMA on channels A to D. Frames  
13 are not synchronized between channels, as illustrated by the staggered arrangement of the  
14 upstream and downstream frames between the channel.

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16                   In Fig. 4, CPEs A and B are assigned to channel A, CPEs C and D are assigned to  
17 channel B, CPEs E and F are assigned to channel C, and CPEs G and H are assigned to channel  
18 D. Thus, CPEs A and B receive downstream MAP and data bursts from a base station and send  
19 upstream data bursts to the base station on channel A. CPEs C and D receive downstream MAP  
20 and data bursts from the base station and send upstream data bursts to the base station on channel  
21 B. CPEs E and F receive downstream MAP and data bursts from the base station and send  
22 upstream data bursts to the base station on channel C. CPEs G and H receive downstream MAP  
23 and data bursts from the base station and send upstream data bursts to the base station on channel  
24 D.

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26                   As shown in Fig. 4, some of the channels are used to full capacity, preventing

1 additional data from being sent or received on those channels. For example, CPEs A and B  
2 cannot send additional data to the base station on channel A because the upstream frame of the  
3 channel is already fully utilized. Likewise, CPE F cannot send or receive data using channel C  
4 because CPE E is fully utilizing channel C. At the same time, some of the slots in the channels  
5 in Fig. 4 are unused. Thus, conventional channel and slot allocation can be inefficient and can  
6 lead to communication delays.

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8 Summary of the Invention

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10 Accordingly, what is needed is a system that more efficiently utilizes plural  
11 channels in a TDD environment.

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The invention addresses the foregoing need by synchronizing frames across the plural channels so that upstream frames and downstream frames coincide across the plural channels. As a result, slots in all of the synchronized channels are available for use when a CPE needs to upload data to a base station. Likewise, slots in all of the synchronized channels are available for use when the base station needs to download data to a CPE. A controller in the base station can allocate channels and slots in those channels to the various CPEs so as to send or to receive data using slots that would otherwise be unused, thereby more efficiently utilizing the plural channels.

Accordingly, in one embodiment the invention is a method of managing TDD across plural channels. In the method, frames are synchronized across the plural channels so that upstream frames and downstream frames coincide across the plural channels.

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Preferable, one channel is assigned to each of plural CPEs. Each CPE receives

1 MAP messages on its assigned channel. A base station controller preferably generates the MAP  
2 messages. The MAP messages instruct the CPEs to switch channels so as to receive data bursts.  
3 The base station controller preferably includes a centralized scheduler that allocates channels and  
4 slots in those channels to the CPEs for receipt of the data bursts.

5

6 In another aspect, the invention is a method of receiving TDD messages.  
7 According to the method, CPEs switch channels based on received MAP messages so as to  
8 receive data bursts on plural channels. The channel to which a CPE switches need not be the  
9 same channel as the one on which the CPE receives its MAP messages.

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11 By virtue of the foregoing operations, the invention allows for more efficient use  
12 of channels in a TDMA environment. In particular, if a first channel on which a CPE receives  
13 MAP messages is full, a base station can allocate a slot in another channel to the CPE. The use  
14 of a centralized scheduler facilitates this cross-channel slot allocation.

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16 The invention also can be embodied in communication systems, base stations  
17 and/or CPEs that utilize the foregoing methods. Other possible embodiments of the invention  
18 include software for implementing the foregoing methods. Additional embodiments of the  
19 invention are possible.

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21 This brief summary has been provided so that the nature of the invention may be  
22 understood quickly. A more complete understanding of the invention may be obtained by  
23 reference to the following description of the preferred embodiments thereof in connection with  
24 the attached drawings.

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1                   Brief Description of the Drawings

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3                   Figure 1 shows a communication system in which the invention can be  
4                   implemented, including a base station and plural CPEs.

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6                   Figure 2 shows frame synchronization and cross-channel slot allocation according  
7                   to the invention.

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9                   Figure 3 shows a communication system in which the invention can be  
10                  implemented, including an alternative implementation of the base station.

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12                  Figure 4 shows channel slot allocation according to the prior art, in which  
13                  channels are not synchronized.

1                   Description of the Preferred Embodiment

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3                   In the following description, a preferred embodiment of the invention is described  
4                   with regard to preferred steps and data. However, those skilled in the art would recognize, after  
5                   perusal of this application, that embodiments of the invention may be implemented using one or  
6                   more general purpose processors or special purpose processors adapted to particular steps and  
7                   data operating under program control, that such process steps and data structures can be  
8                   embodied as information stored in or transmitted to and from memories (e.g., fixed memories  
9                   such as DRAMs, SRAMs, hard disks, caches, etc., and removable memories such as floppy  
10                  disks, CD-ROMs, data tapes, etc.) including instructions executable by such processors (e.g.,  
11                  object code that is directly executable, source code that is executable after compilation, code that  
12                  is executable through interpretation, etc.), and that implementation of the preferred steps and data  
13                  described herein using such equipment would not require undue experimentation or further  
14                  invention.

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16                  Fig. 1 shows a communication system in which the invention can be implemented,  
17                  including a base station and plural consumer provided equipment (CPEs). In Fig. 1, base station  
18                  1 communicates with CPEs 2 using antennae 3. Examples of CPEs 2 include wireless digital  
19                  phones, personal data assistants (PDAs) with wireless modems, and other devices that can utilize  
20                  time division duplexing (TDD). Preferably, CPEs 2 include at least transceivers that can  
21                  dynamically switch between plural channels and controllers for controlling the transceivers.

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23                  Base station 1 preferably includes at least data and other I/O 5 for sending data to  
24                  and receiving data from an outside source. Examples of the outside source include, but are not  
25                  limited to, a computer network, a long-distance or local telephone network, a data network, and  
26                  the World Wide Web. Base station 1 preferably also includes transceiver 6 for transmitting and

1 receiving signals over plural channels using antenna 3.

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3 Data and other I/O interface 5 and transceiver 6 are controlled by controller 7 of  
4 base station 1. Controller 7 preferably includes at least a memory and a processor (both not  
5 shown). The memory can be a fixed memory such as DRAMs, SRAMs, hard disks, caches, etc.,  
6 or removable memory such as floppy disks, CD-ROMs, data tapes, etc, or any combination of  
7 these memories. The memory preferably stores information including instructions executable by  
8 the processor and data for use during execution of those instructions. According to the invention,  
9 this data preferably includes at least a schedule of slot allocations across synchronized frames for  
10 plural channels and data for constructing media access protocol (MAP) messages for plural  
11 CPEs.

12

13 Preferably, controller 7 implements all channel control 8 for controlling  
14 communications with CPEs 2 over plural channels. Channel control 8 preferably includes  
15 centralized scheduler 9 that allocates channels and slots in those channels to CPEs 2.

16

17 Fig. 2 shows frame synchronization and cross-channel slot allocation according to  
18 the invention.

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20 Briefly, according to the invention, frames are synchronized across the plural  
21 channels so that upstream frames and downstream frames coincide across the plural channels.  
22 One channel is assigned to each of plural CPEs. Each CPE receives MAP messages on its  
23 assigned channel. Based on received MAP messages, CPEs switch channels so as to receive data  
24 bursts. The channel to which a CPE switches need not be the same channel as the one on which  
25 the CPE receives its MAP messages.

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1                   In more detail, CPEs A to H in Fig. 2 communicate with a base station (not  
2 shown) using TDMA on channels A to D. Downstream and upstream frames are synchronized  
3 across the plural channels. In other words, when one channel is being used for downstream  
4 messages (e.g., from base station 1 to CPEs 2), the other channels also are being used for  
5 downstream messages. When one channel is being used for upstream messages (i.e., from CPEs  
6 2 to base station 1), the other channels also are being used for upstream messages.

7  
8                   Base station controller 7 allocates channels and slots in those channels to the  
9 CPEs, preferably using centralized scheduler 9 of all channel control 8. Then, base station  
10 controller 7 constructs MAP messages for the CPEs and sends those MAP messages to the CPEs  
11 on their assigned channels. Thus, in Fig. 2, MAP messages for CPEs A and B are downloaded to  
12 CPEs A and B on channel A, MAP messages for CPEs C and D are downloaded to CPEs C and  
13 D on channel B, MAP messages for CPEs E and F are downloaded to CPEs E and F on channel  
14 C, and MAP messages for CPEs G and H are downloaded to CPEs G and H on channel D. Then,  
15 the various CPEs switch to the allocated channels for receiving (downloading) and sending  
16 (uploading) data in the subsequent downstream and upstream frames.

17  
18                   Because the upstream and downstream frames are synchronized, a CPE can switch  
19 to any one of the channels to send or to receive data. In addition, the CPEs receive MAP  
20 messages all at once, so they can switch in concert to utilize available channel slots more  
21 efficiently.

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23                   For example, in Fig. 2, data bursts to CPE E are going to fully utilize the  
24 downstream frame of channel C, leaving no slots for downloading data to CPE F on channel C.  
25 If data is going to be available for downloading to CPE F, base station 1 can allocate slot 11 in  
26 channel D to CPE F. This allocation is performed by base station controller 7, which informs

1 CPE F of the allocation in MAP message 12.

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3 Likewise, base station controller 7 can allocate slots for uploading data from  
4 CPEs across the channels. Thus, in Fig. 2, slot 13 in channel B has been allocated to CPE B, slot  
5 14 in channel D has been allocated to CPE A, and slot 15 in channel D has been allocated to CPE  
6 F.

7

8 As shown in Fig. 2, slots in plural channels can be allocated to a single CPE.  
9 Slots can be allocated both on the channel on which the CPE receives its MAP messages and on  
10 other channels. For example, slots in channels A and D have been allocated to CPE A in Fig. 2.  
11 Slots need not be allocated to a CPE on the channel on which the CPE receives its MAP  
12 messages. Thus, CPE F receives its MAP message on channel C and its data burst on channel D.  
13 Any other combinations of channel and slot allocations are possible according to the invention.

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15 The example shown in Fig. 2 is provided only for illustrative purposes. The  
16 invention is not limited to the number and/or arrangement of channels, slots, CPEs, data bursts,  
17 MAP messages, and other details shown in Fig. 2. Instead, the invention encompasses any  
18 multichannel TDD communications in which frames are synchronized across channels, and such  
19 communications in which slots can be allocated across channels.

20

21 Fig. 3 shows another communication system in which the invention can be  
22 implemented, including an alternative implementation of the base station. In Fig. 3, a centralized  
23 scheduler and all channel control are not utilized by base station 20. Instead, controller 21  
24 includes plural channel controllers 22, each with its own scheduler 23. In this embodiment of the  
25 invention, the channel controllers intercommunicate so as to determine slot allocation. One  
26 advantage of this embodiment is that more conventional hardware can be utilized, with a

1 majority of the invention implemented in revised software.

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3 *Alternative Embodiments*

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5           Although preferred embodiments of the invention are disclosed herein, many  
6 variations are possible which remain within the content, scope and spirit of the invention, and  
7 these variations would become clear to those skilled in the art after perusal of this application.  
8 For example, while the plural channels discussed above are plural frequency channels, the  
9 invention is equally applicable to situations where plural different physical channels (i.e., wires  
10 or fiber optics) are utilized, and to combinations of these frequency and physical channels. In  
11 addition, while the invention is disclosed above in a base station/CPE context, the invention is  
12 equally applicable to other point-to-multipoint communications. Other variations are possible.